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13. ABSTRACT *(Maximum 200 words)*

The specific goal of this research was to examine the role of individual differences in cognitive and non-cognitive abilities on individual and team performance in a real-time dynamic team-task environment. The theoretical goal of this research was to improve our understanding of how individual differences relate to team task performance, and to devise objective metrics of team performance. We completed an experiment that required administration of multiple ability tests, developing teams based on ability, and development of computer software to measure individual and team performance. In addition, we constructed an infrastructure of tools including experimental environment, data logging, and data extraction software that will support potential future efforts. Our findings suggest that cognitive and social abilities play a central role individual team member performance, and in team performance as a whole. Additional analyses of team structure suggest that the lowest-ability team member (the weakest link") determines team performance as a whole. Our findings have direct relevance to the selection, classification, and training of sailors who will serve as members of 21st Century Navy teams.

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FINAL TECHNICAL REPORT

GRANT #: UM03-04-088; ONR Grant #: N000140310621

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INSTITUTION: Mississippi State University

GRANT TITLE: Individual Differences in Cognitive and Noncognitive Abilities and Team Performance in Dynamic Task Environments

AWARD PERIOD: July 1, 2003 to June 30, 2004

OBJECTIVE:

Background

In the 21st century Navy, war-fighting objectives include technological superiority, reduced staffing, and an affordable force. Given the requirement of superior performance with fewer personnel, the Navy has a critical need for research that addresses selection and classification of sailors into billets. The present research investigated the relationship between individual differences in cognitive and noncognitive abilities and performance in interactive task environments at both individual and team levels. Because this research spans multiple disciplines, our research team was structured accordingly. Our collaborative team included electrical and computer engineers, computer scientists, cognitive scientists and cognitive psychologists.

Project Goals

The specific goal of this project was to investigate the impact of individual differences in cognitive and noncognitive abilities on team performance. Cognitive and social psychology measures were used to assess individual differences in cognitive and noncognitive abilities and relate them to a) individual performance and b) team task performance. This research will be useful for expanding measures used to select sailors to serve in the 21st Century Navy. This research will address issues important to sailor selection and classification into billets that require team-intensive skills, including structuring teams according to team-member abilities.

A vast literature exists on leadership and team abilities, although much is considered to be anecdotal or theoretical in nature (Bartone, Snook, & Tremble, 2002; Brannick, Roach, & Salas, 1993; Druckman, Singer, & Van Cott, 1997, p. 98; LePine, 2003; Stout, Salas, & Fowlkes, 1997). There have been recent studies that provide support for the role of cognitive abilities, such as problem solving (e.g., Phillips & Hunt, 1992; Fiore, Cuevas, Scielzo, & Salas, 2002), and noncognitive factors, such as personality traits (e.g., Bass, 1990; Mohammed, & Angell, 2003; Porter, Hollenbeck, Ilgen, Ellis, West, & Moon, 2003), in leadership and team-related performance. However, to our knowledge there are no published studies that examine the role of individual differences in cognitive and noncognitive abilities in team performance in a dynamic, interactive team task environment. There are studies that use what are termed "microworlds", where an individual subject may control a team of computer agents, but the subject is not working as a team member per se (e.g., Rigas, Carling, & Brehmer, 2002; but see Cooke, Kiekel, & Helm, 2001).

In the military operational environment, sailors serve as members of a team charged with working toward a common goal. The operational environment is dynamic, where the state of world can change quickly, and the team must adapt to the changes to achieve their mission. There is usually a hierarchical structure to the team, where an operational supervisor (e.g., a commander) is responsible for the success of the mission, but relies upon multiple personnel to execute the requisite mission tasks. For operational teams to accomplish their mission, they must develop a shared understanding of their operational environment, communicate that shared understanding, and do so in a timely fashion to keep pace with the dynamic changes caused by actions of the enemy, environmental influences, and so on.

In order to achieve our goal, we sought to emulate the characteristics of this type of operational environment. That is, our tasks took place in dynamically changing environments in which team members were often required to coordinate their actions in order to achieve optimal team performance. Our goal was achieved by relating performance metrics on these tasks to measures of individual differences in cognitive and noncognitive abilities. Measures of verbal comprehension, spatial orientation and visualization, and general reasoning ability served as

cognitive ability measures. Measures of social intelligence and personality (e.g., five-factor personality inventory) factors served as noncognitive measures.

In the current research, team performance was measured in a dynamic and interactive task environment that served as an analogue to the military operational environment just described. Specifically, participants served as team members in a computer game called "Half-Life" (Le, 1998). For the current research, a set of twelve tasks was developed in the computerized Half-Life environment. These twelve tasks were designed to provide measurement opportunities for multiple dimensions of teamwork (Dickinson & McIntyre, 1997). In each task, the participants were required to escort a preprogrammed VIP (i.e., VIP movements were predetermined through the computer program) to a target destination. In addition to the human team members and the computerized VIP agent, the environments contained two other types of computer-controlled agents. Hostile agents would fire at the VIP or the team members. Neutral agents would walk in the environment but not pose a threat to the VIP. Team members were instructed not to damage neutral agents. See Figure 1[1] for an example illustration of the environment with specific elements described in greater detail.

APPROACH:

In order to assess the role of individual differences in individual and team performance, several factors had to be considered during our research. First, a set of ability tests needed to be chosen in order to capture the relevant attributes of team members that might be useful in predicting task performance. Second, given the results of the ability tests, an experimental design had to be constructed that would allow us to study the relative impact of cognitive and noncognitive abilities on task performance. Finally, a set of tasks had to be constructed in a manner that would both reflect the attributes of the operational environments relevant to the Navy and provide ample opportunities to measure performance in a systematic way. Each of these topics will be discussed in turn.

Measuring Individual Differences

In order to measure individual differences in cognitive and noncognitive abilities, all participants completed a battery of tests. This battery of tests was selected following discussions with personnel at NPRST. The test battery included four cognitive ability tests that measured verbal, spatial, and general reasoning abilities. Specifically, the four tests chosen were: Raven's Standard Progressive Matrices (Raven, 1938), Integrating Details (Alderton, 1989), Thurstone's Perceptual Speed (Thurstone, 1983), and Nelson-Denny Vocabulary (Brown, Bennett, & Hanna, 1981). Figures 2 through 5 depict screenshots of the cognitive ability tests used in our study. The battery also included three noncognitive ability tests that measured various aspects of personality and social abilities. Specifically, the three tests were the International Personality Item Pool (IPIP; Goldberg, 1999), the Enlisted Navy Computer Adaptive Personality Scales (ENCAPS; Farmer & Bearden, 2004), and the Positive and Negative Affect Scale (PANAS; Watson, Clark, & Tellegen, 1988). The seven-test battery was administered in approximately two hours over a two-day period. Following completion of the test battery, we performed a principal components factor analysis on the cognitive battery results to determine if a subset of the scores could be grouped together into a cognitive factor ability. The results showed that the four cognitive tests loaded significantly on a single factor. We therefore calculated a single cognitive factor score for each participant and used that score in defining our groups (discussed below). Similar analyses of the noncognitive scores resulted in multiple factors. Because of the limitations in the size of and funds for a participant pool, we needed to select one noncognitive factor for noncognitive grouping. To do this, we consulted with subject-matter-experts (SMEs) from NPRST including Drs. David Alderton, William Farmer, Tanja Blackstone, and Jacqueline Mottern. The SMEs recommended using Social Orientation from the ENCAPS test as the noncognitive measure of interest for dividing participants into groups.

Experimental Design and Tasks

One hundred forty-seven participants were recruited to take our battery of cognitive and noncognitive ability tests. The 147 participants were later divided into teams based on the results of the test battery and the need for a balanced design. Our final experimental design called for four groups of participants. The first group of participants (HH) was high in cognitive ability and high in noncognitive ability (i.e., Social Orientation). The second group of participants (HL) was high in cognitive ability, but low in noncognitive ability. The third group of participants (LH) was low in cognitive ability, but high in noncognitive ability. The fourth group of participants (LL) was low in cognitive ability and low in noncognitive ability. Recall that the cognitive test scores loaded on a single factor. That factor score defined cognitive grouping. Scores on the Social Orientation scale from ENCAPS defined noncognitive grouping.

[1] All Figures and Tables are included in the Appendix

Once classified into one of the four possible groups, participants were placed in teams that would work together to complete the experimental tasks. Each team was composed of three members; one leader and two subordinates. The team leaders were always from the HH group. Team subordinates were from one of the four groups. Within each team, subordinate ability was held constant. That is, they were either both HH, both HL, both LH, or both LL. Table 1 shows the four team types and the number of each type of team that completed the entire experiment.

Teams were run through a series of tasks developed in the "Half-Life" computer game. As previously mentioned, the teams were assigned to escort a computer-controlled VIP to a target destination while protecting him from hostile agents. In addition to that general goal, each of the twelve tasks took place in a different computer generated "environment" that imposed a unique challenge. For example, in one of the twelve tasks, the VIP would walk through the environment until encountering an obstacle that blocked his path (see Figures 6a – 6e). The team members had to split up to achieve both goals. That is, they had to disperse in order to both protect the VIP and find a button in the environment that would remove the obstacle and let them proceed to the target destination. See Figures 6 and 7 for example illustrations of what the tasks looked like to the team members and examples of other challenges the teams had to overcome.

Each task provided multiple opportunities to measure individual and team performance. We collected significantly more data than we are able to analyze in a one-year project. Our analysis included an important subset of the measures, and the measures analyzed fell into one of three categories or sets. The first set measured individual performance. The measures included "individual damage per engagement," "individual total player damage," "individual shots per kill," "individual time per kill," and "individual percent of ammunition used on hostiles." A more detailed description of each individual performance measure is provided in Table 2. The next set included composites of the individual measures. That is, we calculated a team level score for each of the individual level measures. For example, each team member had three "individual damage per engagement" scores, but the scores were averaged across the three team members to calculate a "team composite damage per engagement" score. See Table 3 for a description of composite team measures. All of these composite measures are a function of the individual measures, but are influenced by how well the team coordinates their actions. This is particularly the case for "team composite damage per engagement" and "team composite total player damage." Coordinated actions in combat lead to fewer opportunities for enemy agents to score hits. So, a well-coordinated team would have a lower damage score. Finally, the third set of measures represent purely team level scores that are not a function of individual member performance. The measures include "team time to completion," "team VIP damage," "team percent time VIP guarded," and "team percent time VIP in danger." For a more detailed description of each of the team measures, see Table 4.

<u>ACCOMPLISHMENTS</u> (throughout award period):
We accomplished our goal of studying the impact of cognitive and noncognitive abilities on individual and team performance. To accomplish this goal, we administered a set of ability tests, constructed specific sets of teams, and measured performance on a carefully constructed set of tasks. Our analyses of the performance measures at the individual and team levels will be discussed in turn below. In addition to fulfilling this main goal of the research, we constructed an infrastructure to support this effort and potential future efforts. The specific tools we have developed as part of our infrastructure are discussed below as well.

Performance Measure Analyses
The individual, team composite, and team measures described above, were used to derive individual and team level factor scores using a principal components factor analysis with Promax rotation. The team level analysis included the team composite measures and the team measures. Tables 5 and 6 show the results of these analyses in detail. Two individual measure factors accounted for 70% of the variance in the data. We labeled the factors "combat effectiveness," and "shooting efficiency" (see Table 5). At the team level, three factors accounted for 68% of the variance in the data. We labeled these factors "coordinative ability," "VIP protection," and "shooting type" (see Table 6). After calculating individual and team level scores for each factor, our next step was to relate those factor scores to the cognitive and noncognitive abilities previously measured for each participant.

Individual Performance Analyses
Our goal was to relate individual measure factor scores to individual difference measures. We performed two regression analyses using the factor scores as dependant variables to be predicted by a set of independent variables consisting of either the individual cognitive and IPIP scores, or the individual cognitive and ENCAPS scores. Tables 7 and 8 summarize the significant results from these analyses. To briefly summarize, results from the first

regression indicate that cognitive ability and scores on the IPIP (especially Neuroticism) predicted "combat effectiveness," accounting for 21% of the variance in the data. That is, higher cognitive ability and higher emotional stability yielded better factor scores on "combat effectiveness," a factor that measured the average amount of damage taken in each engagement and each task as a whole. Additionally, results from the second regression indicate scores on the ENCAPS test (especially Social Orientation) predicted "shooting efficiency," accounting for 7% of the variance in the data. That is, higher Social Orientation scores yielded better scores on "shooting efficiency," meaning individuals took fewer shots and less time to eliminate hostile agents, but tended to waste more ammunition. One possible reason for this relationship might be that individuals with higher Social Orientation are more likely to respond to feedback from other team members about efficient methods of eliminating hostiles (e.g., aiming for critical targets like the head). Overall, these analyses suggest that individual performance metrics on a dynamic, team task can be predicted by measures of cognitive and noncognitive abilities.

Team Performance Analyses
While individual level performance is important, such analyses do not address the effects of team composition on performance. To fully explore the effects of team composition on team performance, we used multiple analysis approaches. The team composite and team measures were both used in the following analyses. Recall that team level variables are independent of individual level performance measures (see Table 4), while composite team measures were calculated by averaging individual performance measures (see Table 3).

<u>Team Composition</u>
We examined the effect of team composition (as defined in our experimental design, see Figure 8) on team composite and team measures of performance. Recall that these measures loaded significantly on three factors in a principal components factor analysis (i.e., "coordinative ability," "VIP protection," and "shooting type;" see Table 6). An analysis of variance was performed with team composition (i.e., high cognitive, high noncognitive; high cognitive, low noncognitive; low cognitive, high noncognitive; or low cognitive, low noncognitive) as a between subjects variable, and each of the three team performance factors as within subjects variables. There was a significant effect of team composition on "coordinative ability," $F\,(3, 40) = 4.15, p < .02$. Further, we performed a separate 2 x 2 analysis of variance to determine if one component of the team composition (i.e., cognitive or noncognitive) or the interaction of the two was contributing most to the effect. We used team cognitive composition (i.e., high or low) and team noncognitive composition (high or low) as between subjects variables, and the "coordinative ability" factor scores as within subjects variables. There was a main effect of the cognitive component, $F\,(1, 40) = 10.93, p < .01$, but no significant effect of the noncognitive component or the interaction. This implies that cognitive ability and not Social Orientation is the primary factor in a team's "coordinative ability." No significant effects for team composition (as defined in our experimental design) were found for the other two dependant variable factors.

<u>Team Composition Models</u>
In addition to analyzing team performance as a function of our experimentally controlled team compositions, we evaluated a set of potential team performance 'models' to explore the dynamics of team performance in more detail. The goal of using these models was to understand more about how the structure of member cognitive and noncognitive scores contributed to team level performance. The models we used were called "compensatory," "synergy," "weakest-link," and "average" models; and each is discussed below. For each model, we performed two sets of regression analyses. The first set used cognitive ability and IPIP scores as predictors, while the second set used cognitive ability and ENCAPS scores as predictors. These analyses allowed us to determine the contributions of noncognitive abilities measured by the IPIP scales separately from the contribution of noncognitive abilities measured by the ENCAPS scales.

The compensatory model evaluates the hypothesis that the team's performance can be best predicted as a function of the best scores (i.e., cognitive and noncognitive ability scores) represented on the team. To test the compensatory model, we found the highest score for cognitive and for each noncognitive ability on the team and related those scores to the team performance measures. The compensatory model did not significantly predict any of the team factor scores, thus we conclude that the team's strongest member is not the primary contributing factor to team performance.

Next, the synergy model evaluates the hypothesis that the team's performance can be best predicted by the interaction of the individual team member scores. To test the synergy model, we calculated a product term for each team's cognitive and noncognitive abilities and related those product terms to the team performance measures. The significant results of the synergy model are shown in Tables 9a and 9b. The cognitive and IPIP scores in the

synergy model significantly predicted "VIP protection," accounting for 17% of the variance in the data. The cognitive and ENCAPS scores in the synergy model significantly predicted "shooting type," accounting for 20% of the variance in the data.

The third model, "weakest-link," evaluates the hypothesis that the team's performance can be best predicted as a function of the lowest scores represented on the team. To test the weakest-link model, we found the lowest score for cognitive and for each noncognitive ability on the team and related those scores to the team performance measures. The significant results of the weakest-link model are shown in Tables 10a through 10d. The cognitive and IPIP scores in the weakest-link model significantly predicted "coordinative ability," accounting for 36% of the variance in the data. The cognitive and IPIP scores in the weakest-link model also predicted "VIP protection," accounting for 32% of the variance in the data. The cognitive and ENCAPS scores in the weakest-link model predicted "shooting type," accounting for 23% of the variance in the data.

Finally, the average model evaluates the hypothesis that the team's performance can be best predicted as a function of the mean scores represented on the team. To test the average model, we calculated the mean score for cognitive and for each noncognitive ability on the team and related those scores to the team performance measures. The significant results of the average model are shown in Tables 11a through 11d. The cognitive and IPIP scores in the average model significantly predicted "coordinative ability," accounting for 27% of the variance in the data. The cognitive and IPIP scores in the average model marginally predicted "VIP protection," accounting for 15% of the variance in the data. The cognitive and ENCAPS scores in the average model predicted "shooting type," accounting for 14% of the variance in the data.

Taken together, the results of these analyses show that the weakest-link model accounts for the most variance in the data, consistent with findings obtained in previous research (e.g., LePine, Hollenbeck, & Ilgen, 1997). This finding is important to consider when structuring teams. One possible conclusion from these analyses is that weaker members should not be included in teams that are assigned to highly critical team tasks. This is because the weakest member appears to dictate overall team performance.

Individual Differences and Team Performance

A final set of analyses we performed examined the relationship between cognitive and noncognitive abilities and team performance regardless of team composition. That is, we used the set of ability scores from each team member together in a set of regression analyses to predict the team factor scores as dependant variables. This is essentially a 'many-to-one' approach as illustrated in Figure 9. The results of these analyses are shown in Tables 12 through 14. The findings show that cognitive ability and IPIP scores (particularly Neuroticism and Extraversion) predict "coordinative ability," accounting for 40% of the variance in the data. That is, teams with higher cognitive ability, higher emotional stability, and less extraverted team leaders had better scores on "coordinative ability," taking less time to complete tasks, and less damage during the tasks. IPIP scores (Neuroticism and Extraversion) also predicted "VIP protection," accounting for 35% of the variance in the data. That is, teams with more emotional stability and less extraverted team leaders had better scores on "VIP protection," leaving the VIP unguarded less of the time, and keeping the VIP from taking as much damage during the tasks. The third dependant factor, "shooting type" was predicted by scores on the ENCAPS test, accounting for 33% of the variance in the data. That is, teams with higher Achievement Motivation, higher Social Orientation, and higher Stress Tolerance had better scores on the "shooting type" factor, taking less shots and less time to eliminate hostiles; but also tending to waste a larger percentage of their ammunition. These analyses further support the importance of using cognitive and noncognitive measures in selection and classification because the impact of individual differences can be seen both with and without regard to team composition.

Software Tools

Evaluating team performance in a dynamic task is a challenging undertaking that requires the consideration of a number of factors. One factor is that teams function in real time as the environment and situations change around them. Another factor is that a given behavior might have different consequences in different situations and as a result, one must always be aware of context when evaluating team actions. In order to overcome these issues, we developed a number of software tools that we used during this research and that could be easily transitioned to support future research in our lab or shared with other labs. The first tool we developed is a **data-logging tool** that is able to record specific events in the computer-based tasks. For our current research, this tool was used to record many variables such as player and hostile positions, when shots are fired, etc. See Table 15 for a more complete list of the variables this tool can track. The second tool we developed is a **data extraction tool** that applies specific rules to organize the data output by the data-logging tool. Specifically, the data extraction tool extracts the raw data

and then calculates individual and team level scores. The data extraction tool counts the number of times a specific event occurred, and takes into account the contexts (specifics) of the situation at the time of the action. For example, if a participant shot at a neutral agent in the environment during a massive fire-fight with hostile agents, one might choose to score that action differently than if the player had shot a neutral agent during an otherwise calm point in the task. Thus, the data extraction tool was designed to evaluate situations and apply appropriate scoring rules for those situations. The final tool we developed is a **playback tool** that visually displays the locations of the participants and agents in the environment as they moved in real-time through the environment during the experiment. The playback tool is designed to show a 'top-down' or 'bird's-eye' view of the environment in order for viewers to see how the team coordinated their movements during the tasks. Each of these tools was developed using C++ or Visual C++, and is therefore easily portable to other platforms.

CONCLUSIONS:

Cognitive and social abilities predict significant aspects of individual performance on a team and team performance as a whole. This is a substantial finding from this one-year effort to study the relationship between cognitive and noncognitive abilities and performance at the individual and team levels. There are two major categories of deliverables associated with this project. The first is the development of an infrastructure and tools to support team performance research. The second is the experimental collection and analysis of data that was generated from our tasks.

Infrastructure

During the past year, we have developed an infrastructure for conducting team performance research. This infrastructure includes a rich set of tasks in which teams can navigate, carry out simulated battles, and interact with elements in the environment such as doors, buttons, boxes, etc. In addition to the tasks, our infrastructure includes a set of tools capable of collecting real-time performance data, scoring that data, and playing back collected data such as team member movements over the course of a task.

In addition to our rich set of tasks, an experimental methodology was developed that has produced findings consistent with previous real-world research (e.g., LePine, et al., 1997). While other research has examined certain aspects of team performance (e.g., Cooke, et al., 2001), we know of no other research to use tasks as closely analogous to an operational environment. Because of the tools that we have developed, our methodology could be expanded to investigate specific types of military scenarios, or could be converted to studying team tasks in other domains.

Experimental Data

Our efforts in studying team performance have allowed us to determine that a relationship exists between cognitive and noncognitive abilities and individual performance on dynamic tasks. Recall that we found a significant relationship between various ability measures (i.e., cognitive ability, IPIP scores, and ENCAPS scores) and our two dependant variable factors reflecting individual performance (i.e., "combat effectiveness," and "shooting efficiency"). The implication of these findings is that measures of both cognitive and noncognitive abilities will be useful in determining how well an individual will perform on a set of dynamic tasks. In addition, our results showed a relationship between cognitive and noncognitive abilities and team performance. Of particular interest in our team performance level results is that the weakest member of a team has a significant impact on overall team performance. One recommendation that comes from this finding is that weaker members should not be included in teams that are assigned to highly critical tasks. This is because the weakest member appears to dictate overall team performance.

In the current context of operational environments, our research effort has produced strong evidence that individual and team performance can be predicted by measures of cognitive and noncognitive abilities. Including such measures in the Navy's selection and classification process would be of great benefit and could bring the Navy closer to achieving its goal of having a superior force with fewer personnel. As a final note, we have collected a very rich data set of which we have only analyzed a subset. We plan to continue our analysis of these data and publish our future findings in relevant scientific journals.

SIGNIFICANCE:

Given the objective of a superior force with fewer personnel, it is critical that the Navy ensures its selection and classification of sailors is performed in the most beneficial manner possible. The current research has shown that both cognitive and noncognitive factors can affect individual as well as team level performance. One significant recommendation that comes from this research is to include both cognitive and noncognitive measures in the

selection and classification process. Further, it may be useful to look at the profile of sailors based on these cognitive and noncognitive measures before assigning them to team-intensive billets.

PATENT INFORMATION: N/A

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ADDITIONAL LITERATURE REVIEWED:

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APPENDIX:

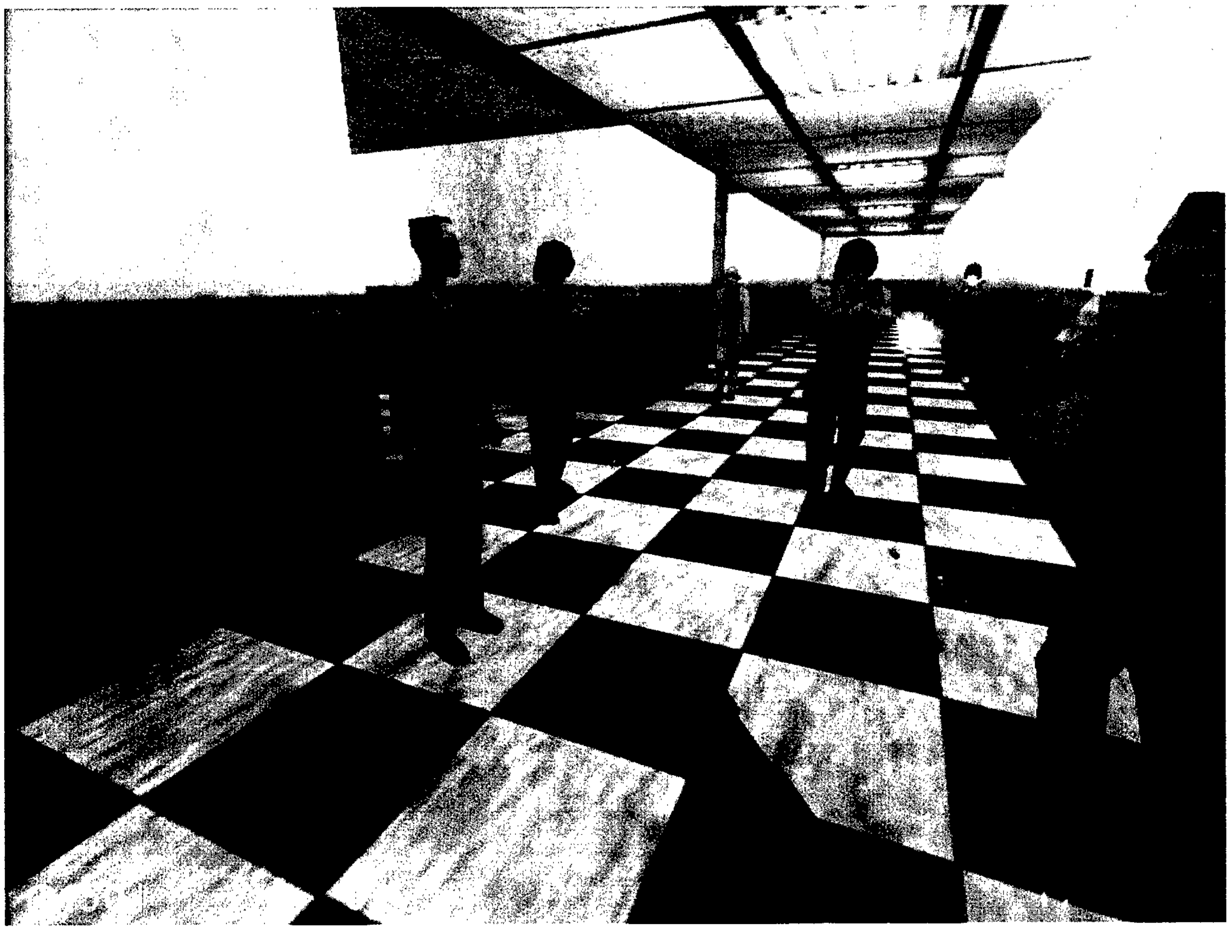


Figure 1. Example task environment in the "Half-Life" game. Each participant views the environment from the first-person perspective and is equipped with a handgun (bottom center) and a radar (top left) that detects the presence of friendly (green circle), neutral (blue square), and hostile (red X) agents in the area. Agents that are out of range appear as question marks on the radar until the team member moves closer to them. Four types of characters exist in the environment. The first are the three human team members (e.g., the green character on the far right) who can see each other in the environment and coordinate their actions. The second type of character is the VIP agent (computerized character; wearing the white coat, near the center of the image) who the participants are assigned to protect from the hostile agents. Next, there are neutral agents in the environment (holding the briefcase in the left side of the image) who the participants are instructed not to injure. Finally, there are hostile agents (wearing the body armor and helmets) who will fire at the team members and VIP.

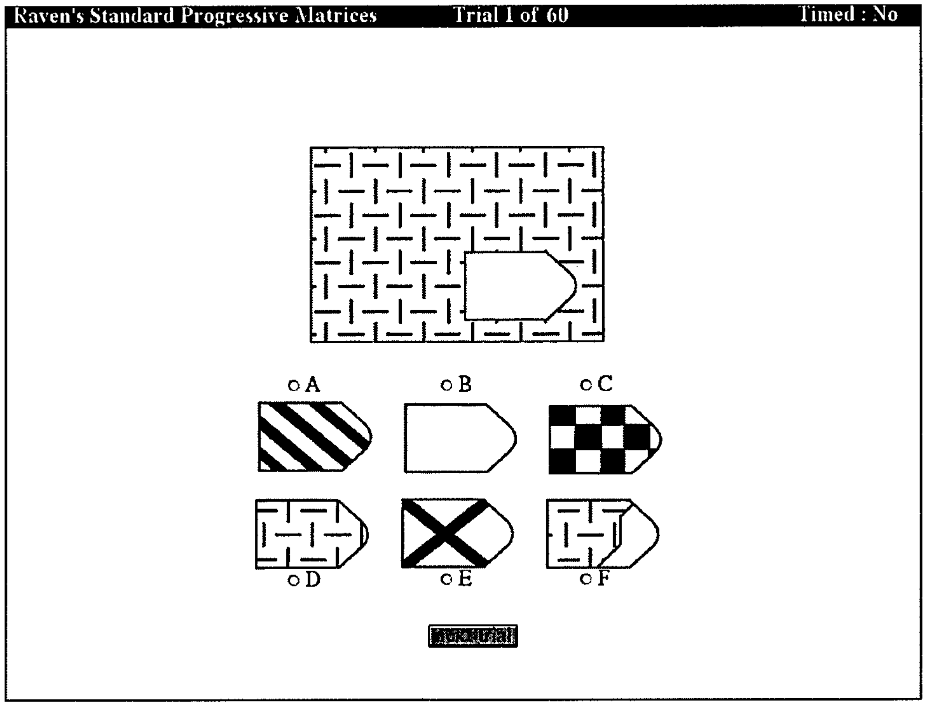


Figure 2. Example trial from Raven's Standard Progressive Matrices.

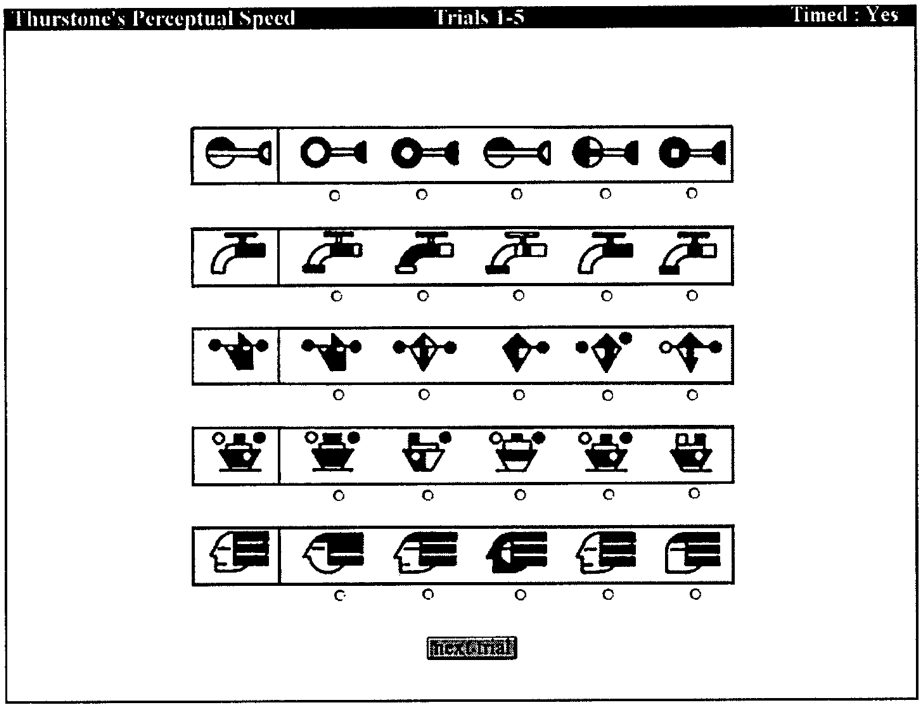
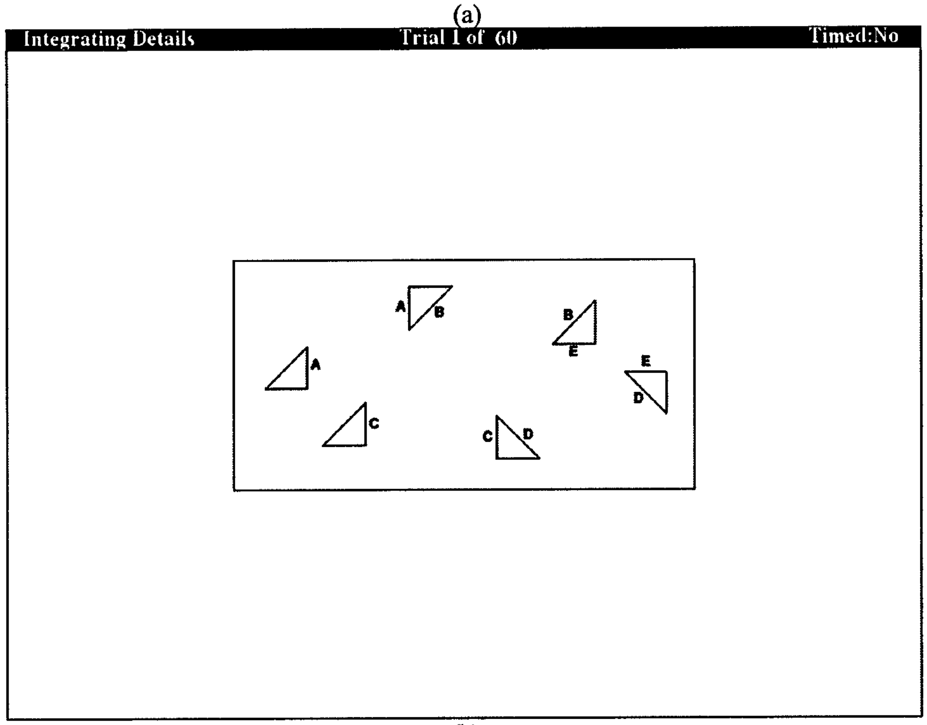


Figure 3. Example trial from Thurstone's Perceptual Speed.

(a)



(b)

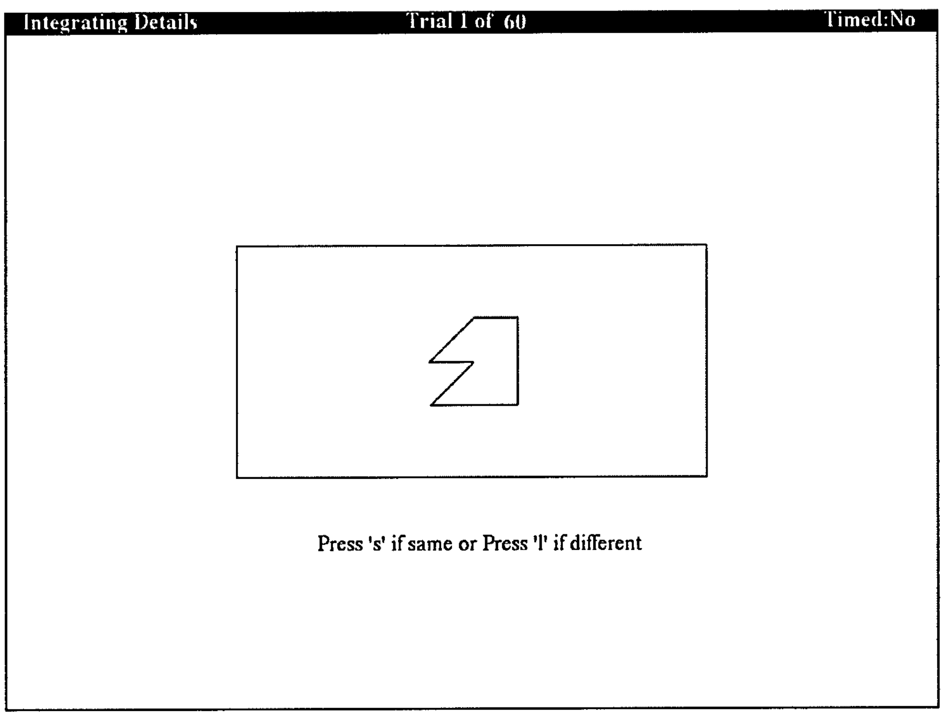


Figure 4. (a) Depicts the first half of an example trial and (b) depicts the second half of an example trial from Alderton's Integrating Details.

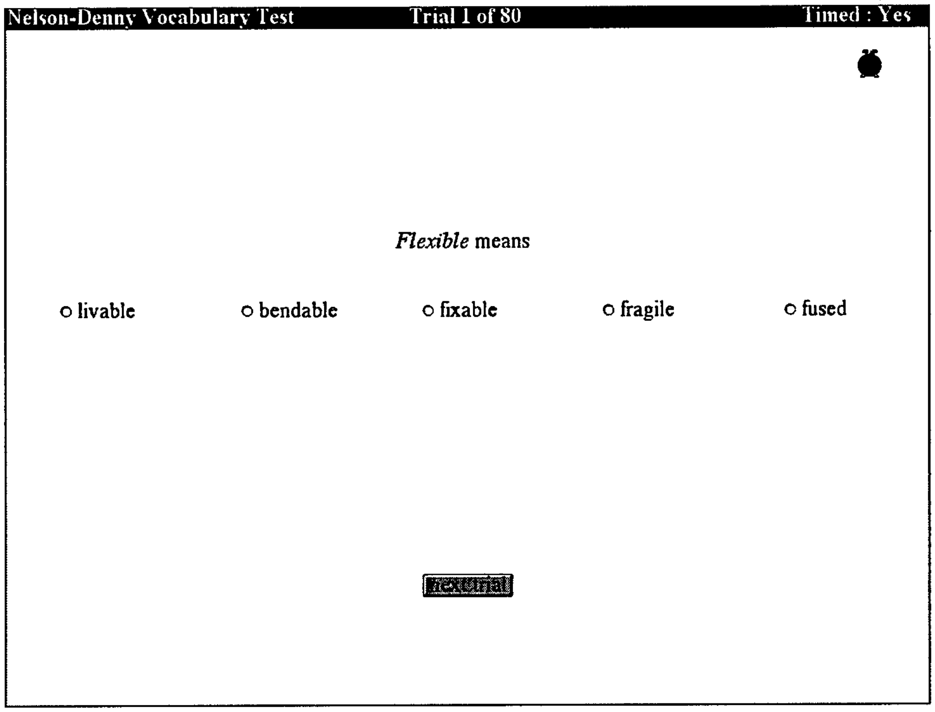


Figure 5. Example trial from Nelson-Denny Vocabulary.

Figure 6a. In one task, the participants are escorting the male VIP towards a target destination when he encounters and obstacle and stops. The team members must find a way to remove the obstacle in order to proceed towards the destination. Since the VIP is potentially in danger, the team members must divide their resources to ensure that the VIP is protected and that someone can search through the environment to find a means of removing the obstacle.

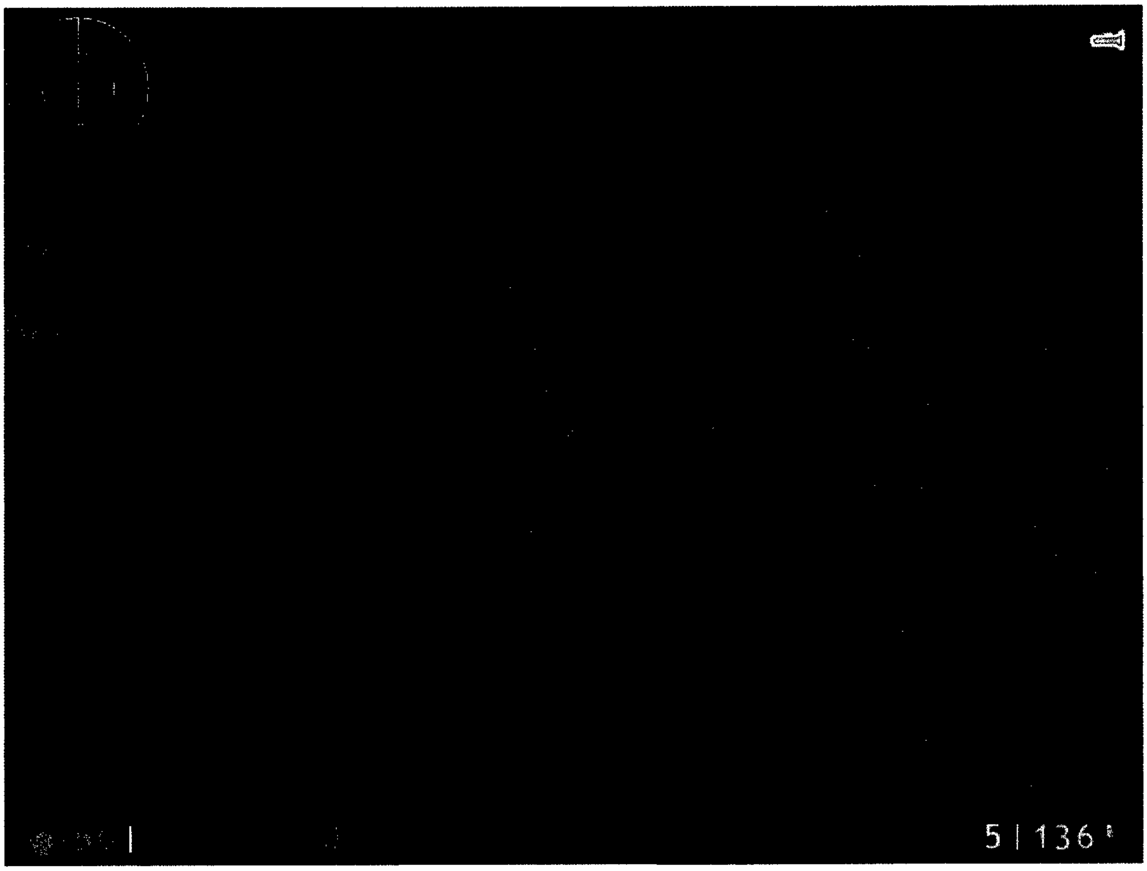


Figure 6b. A button exists in the environment button that will remove the obstacle and allow the VIP to move forward. Team members must search for this button in order to accomplish their goal of reaching the target destination.

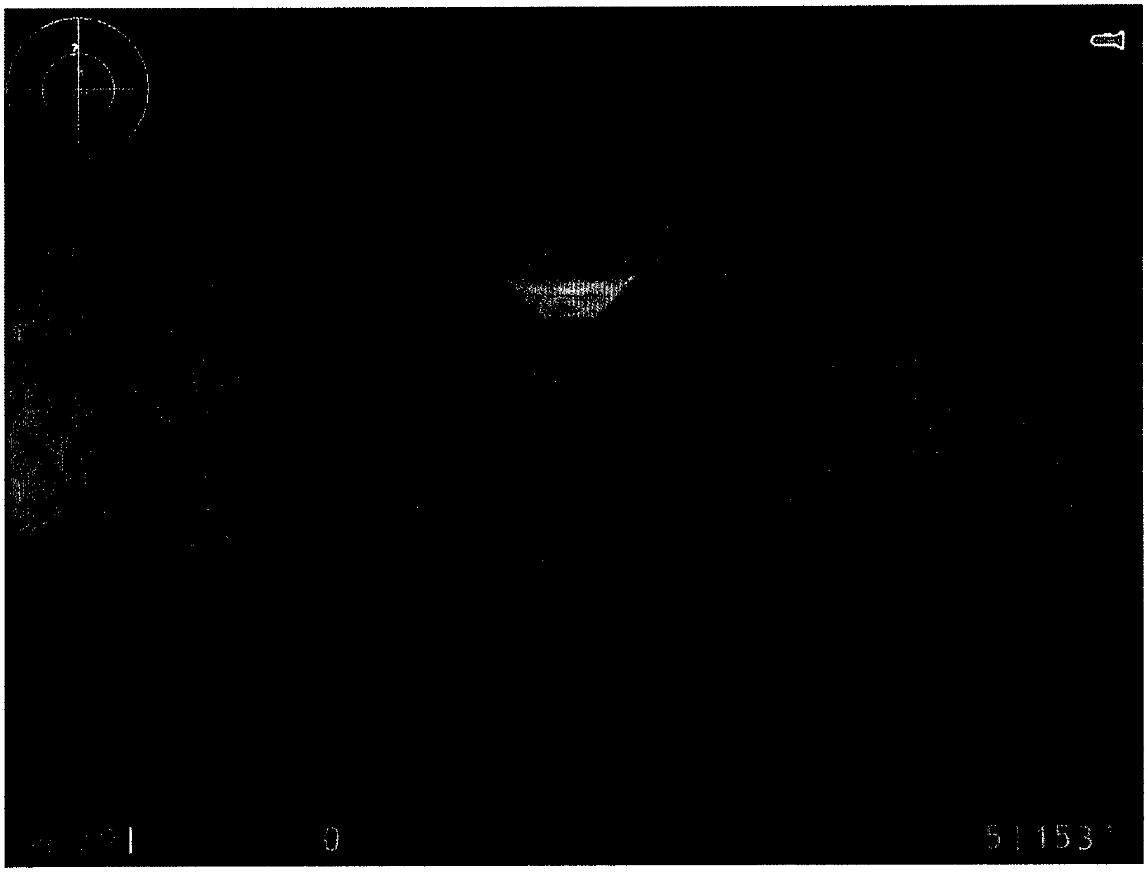


Figure 6c. Hostile agents are positioned throughout the environment, thus it is in the team's best interest to coordinate their actions to avoid being outnumbered by hostile agents and suffering heavy damage. It is also in the team's best interest to move with the VIP at all times to protect him from damage.

Figure 6d. Once the button (Figure 6b) has been pushed, the obstacle is removed and the VIP proceeds towards the destination. If team members are not with the VIP when he begins to move, he might encounter hostile agents and take damage.

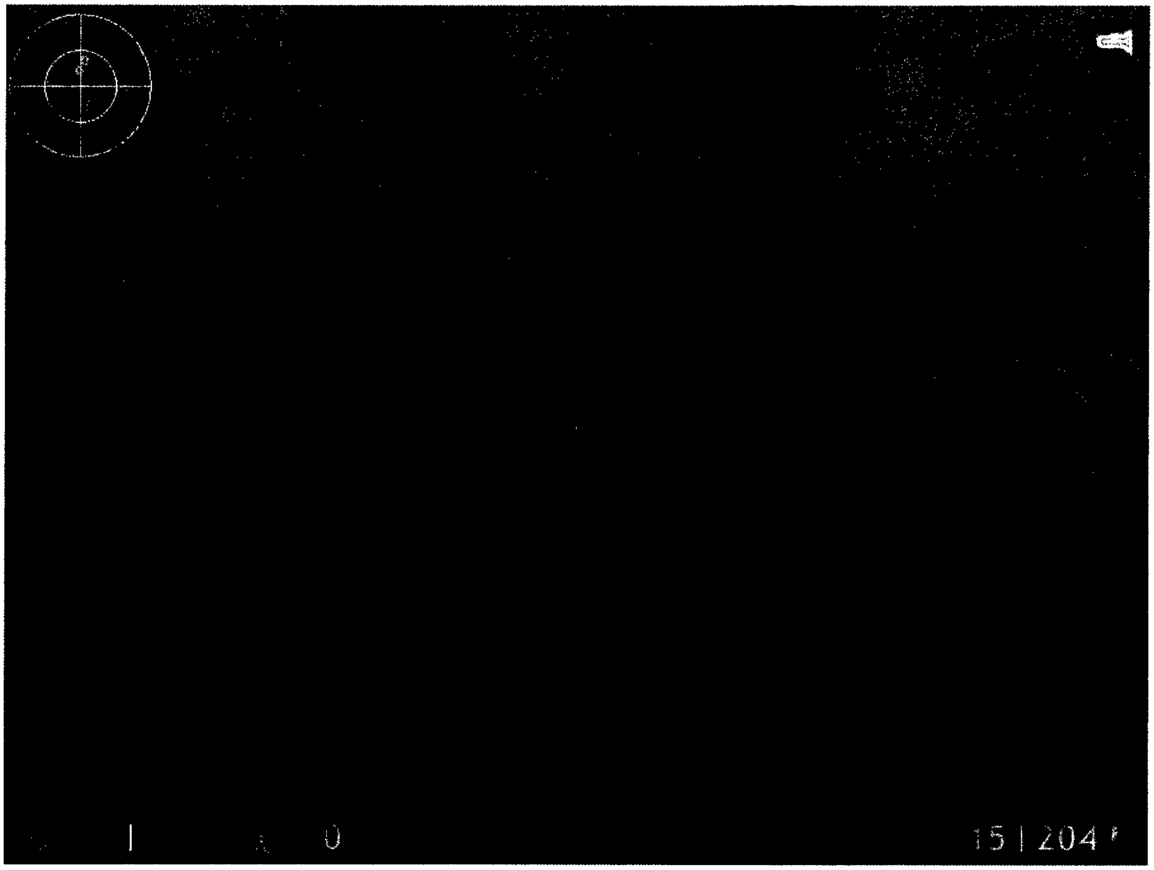


Figure 6e. In each task, team members eventually reach a target destination. When all three team members and the VIP reach the destination, the task is complete.

Figure 7a. In another type of challenge, team members encounter a box that can be used to control a 'train.' One member must stay at the control box to control the train. The optimal solution to the challenge is to have one of the other members ride the train to the otherwise inaccessible parts of the environment, while the third team member stays on the ground level to operate the directional control buttons for the train.

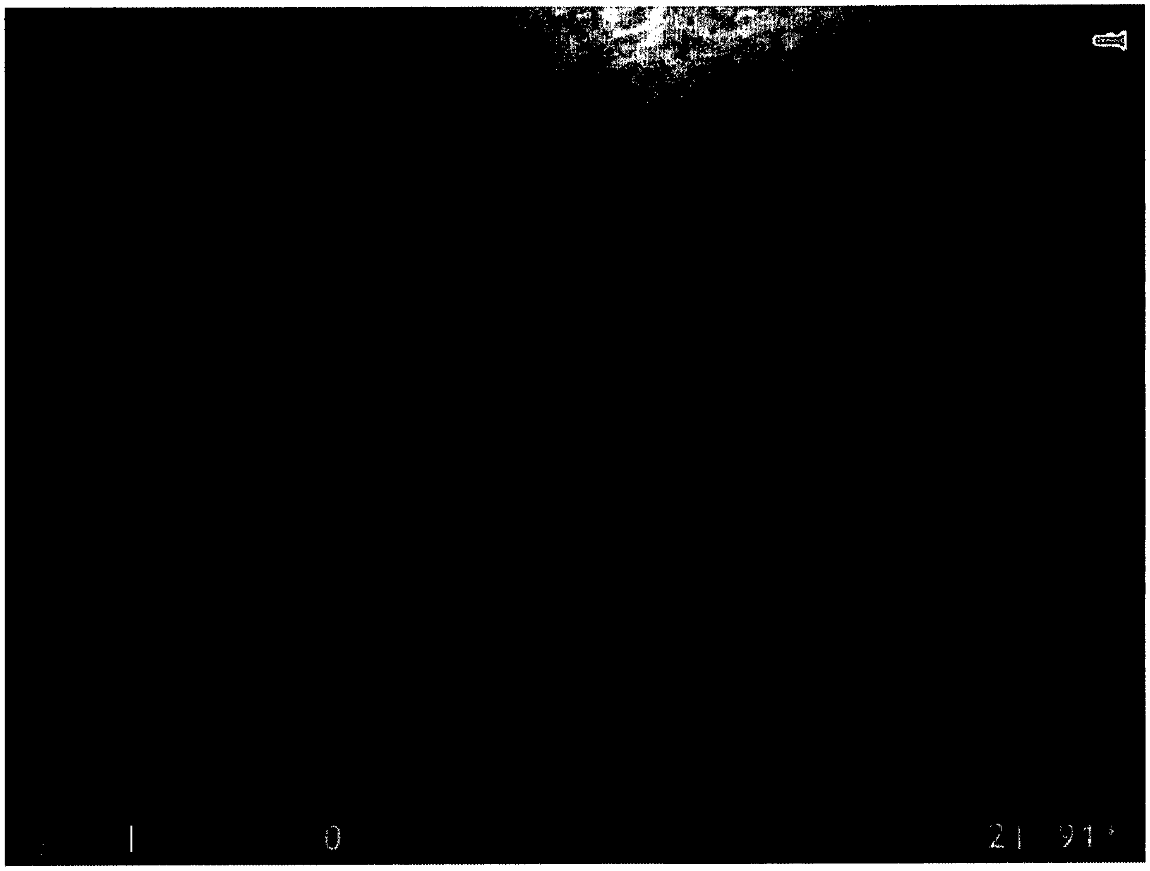


Figure 7b. One team member is riding the train, while another waits below for the rider to open the gate blocking his path.

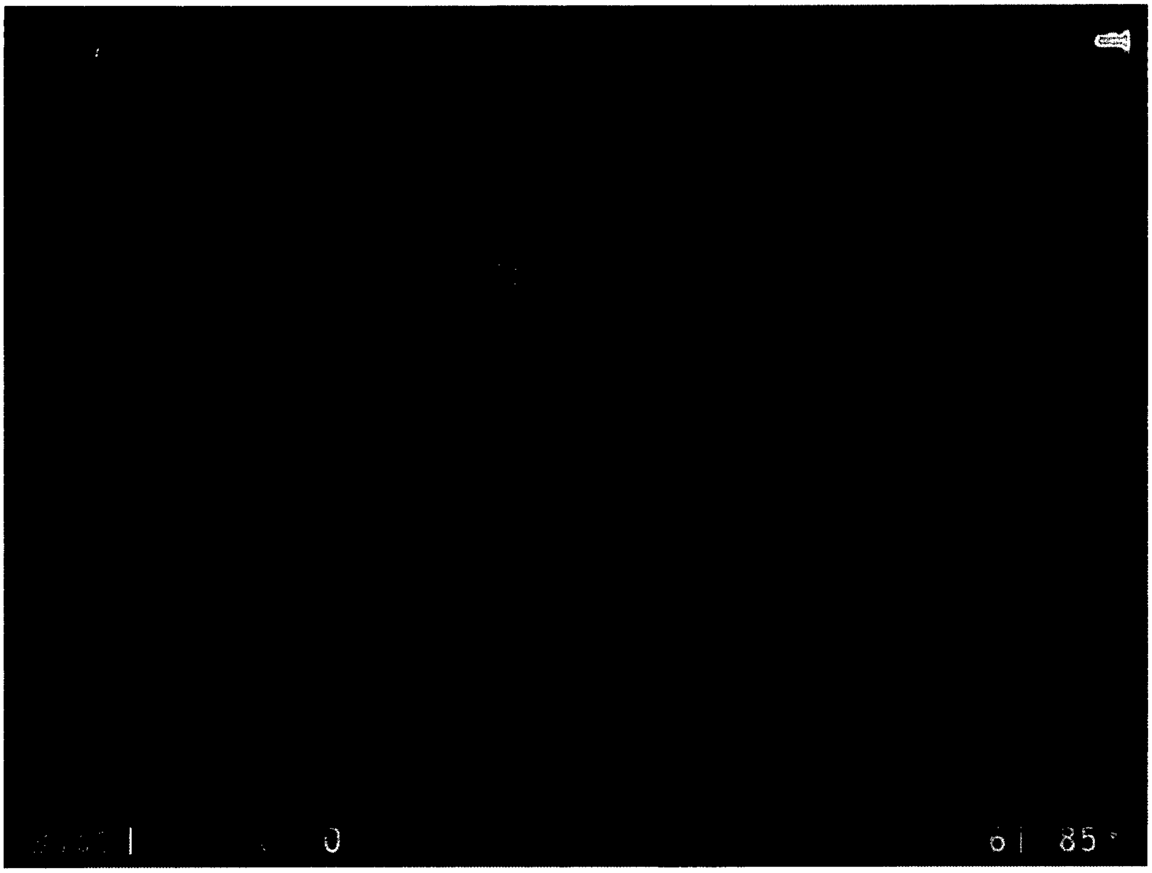


Figure 7c. On the ground floor, buttons are also present. These buttons adjust the direction of the train to allow it to continue along the correct path. When the directional button is pressed, an arrow shown on a display visible to the member riding the train, changes directions.

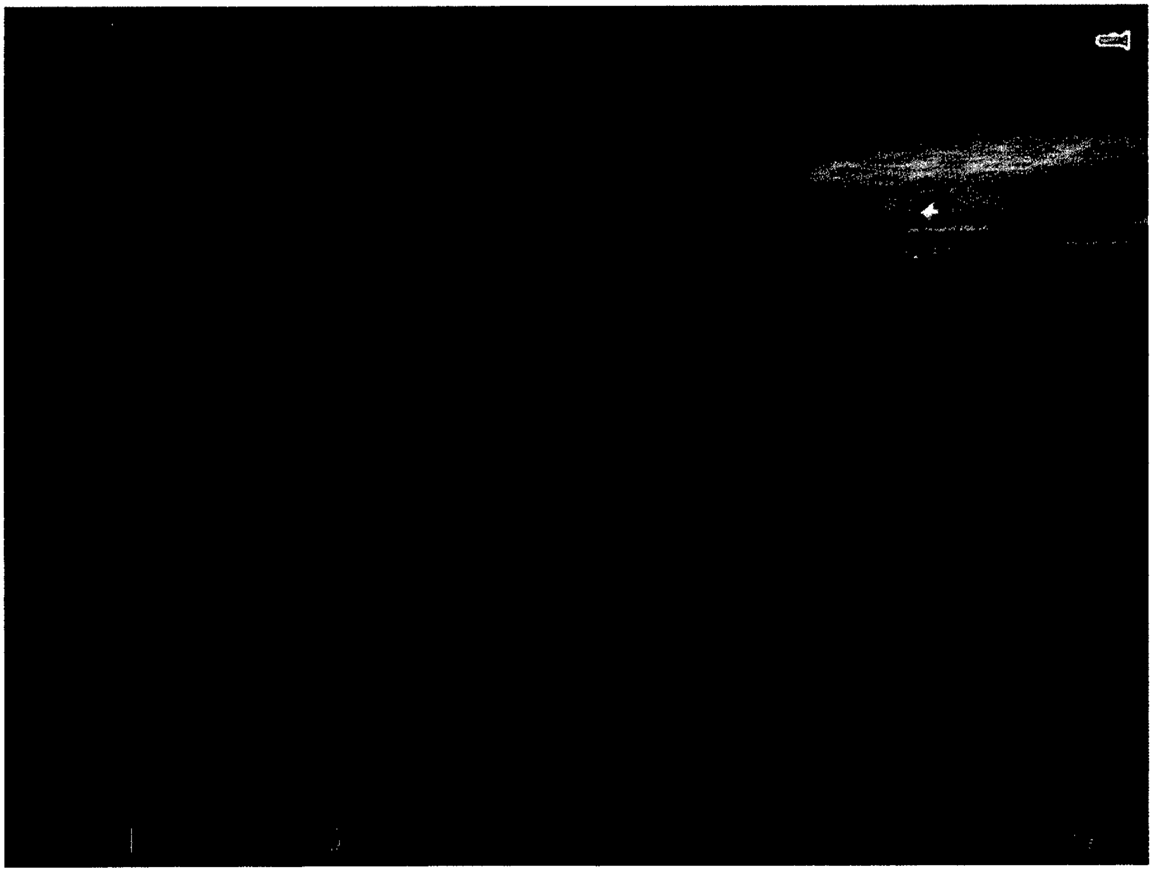


Figure 7d. Buttons are located on the walls that are only accessible from the top of the train. These buttons open the path for other team members to advance in the environment. However, the members not riding the train must be sure to adjust the direction of the train's path, or the train will be stuck in a dead-end. Note the arrow pointing left near the top right of the image. This tells the team member riding the train that he/she will turn left unless something happens to change the direction of the arrow.

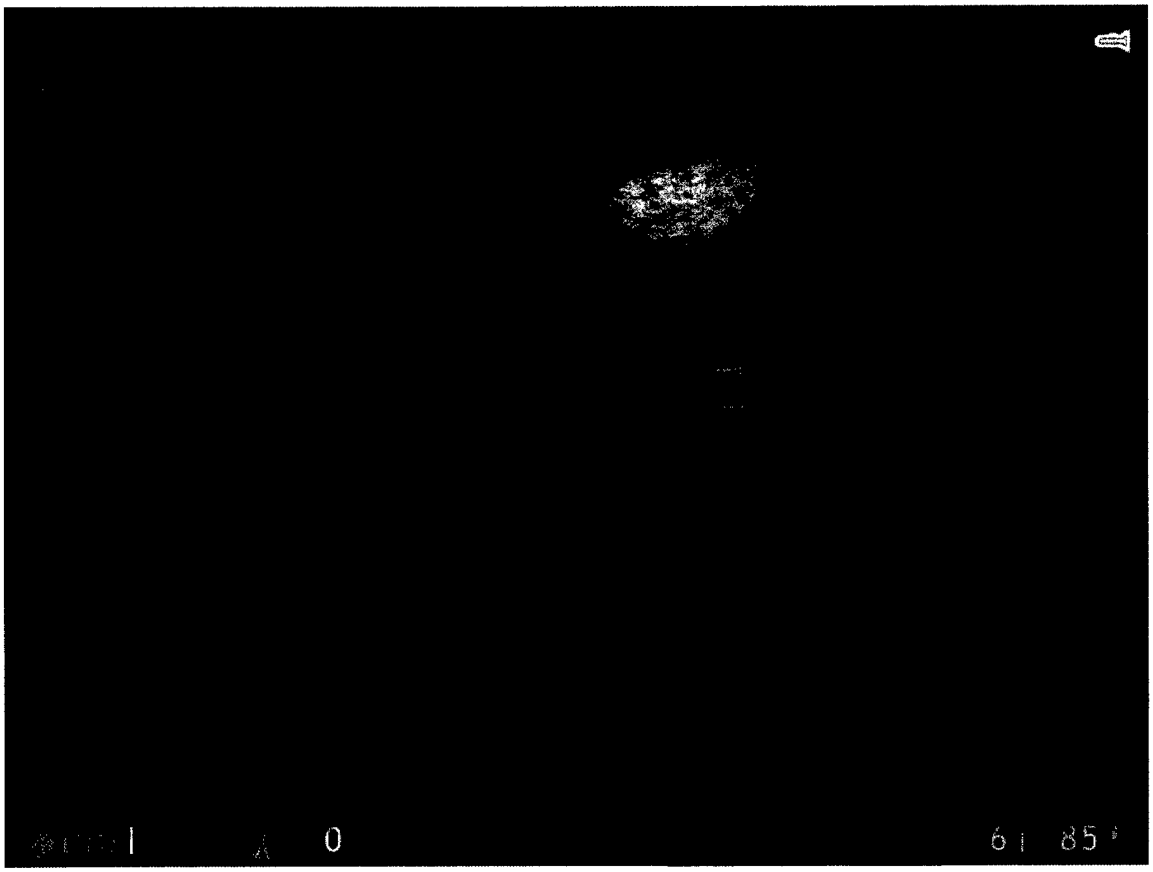


Figure 7e. Once the team member on the train presses a button to open a gate, a team member on the ground can enter the next area through the gate and eliminate any hostiles present. Then, they must press the next directional control button to keep the train on the correct path.

Figure 7f. If the directional button on the ground floor is pressed in time, the train will continue along the correct path and allow the team member on the train to open the next area for the other team members. Teams must work together in a coordinated manner to ensure that all the necessary events take place in the time allotted. After completing this task, the team members will reach a target destination similar to the one shown in Figure 6e.

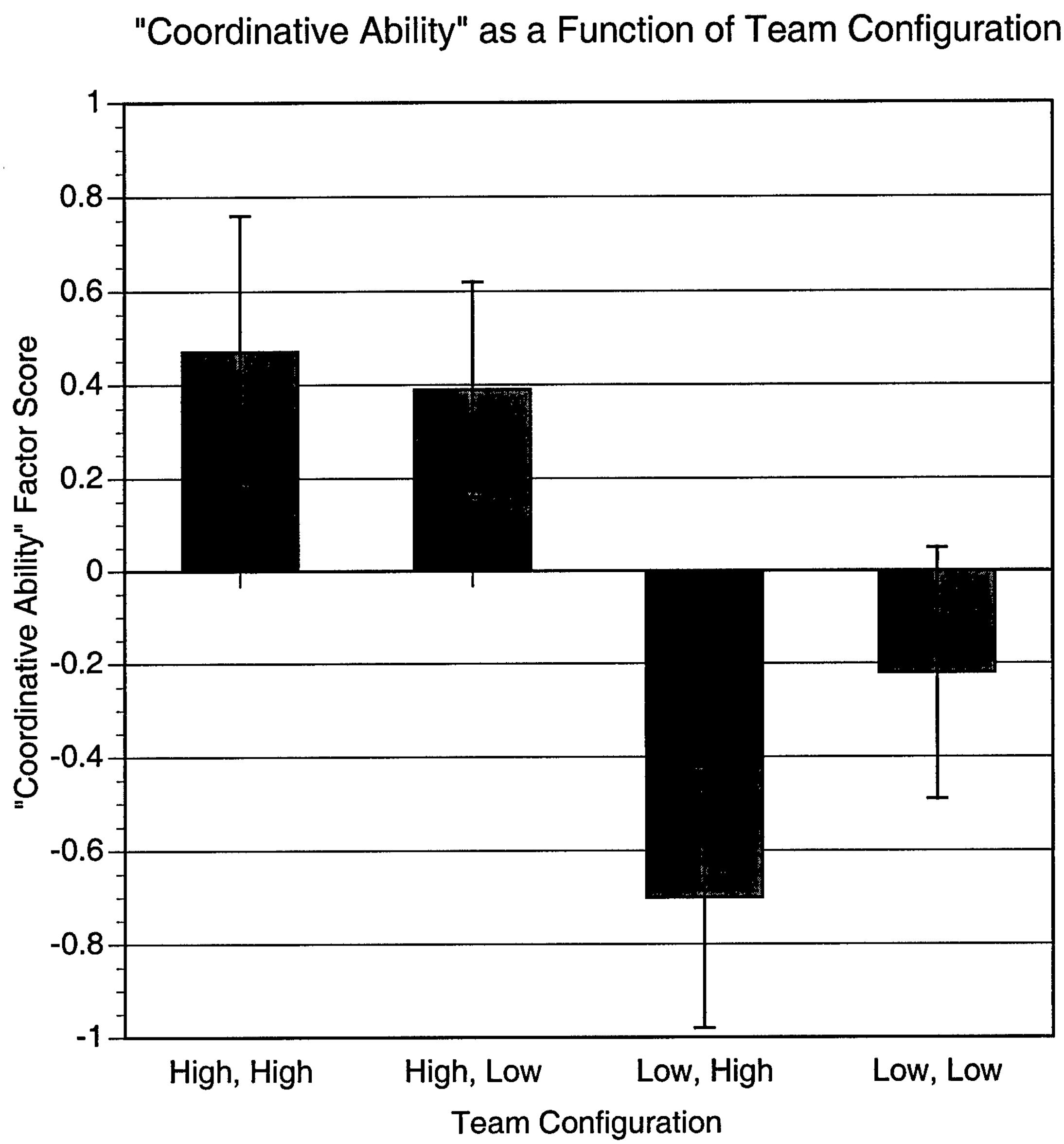


Figure 8. Graph of "coordinative ability" as a function of team configuration. Scores displayed are the inverse of the actual factor scores, such that higher scores on this graph indicate better performance. That is, a higher score corresponds to taking less time to complete tasks and less damage during the tasks. High, High refers to the team members being high in cognitive ability and high in Social Orientation. High, Low refers to the team members being high in cognitive ability and low in Social Orientation, etc. Error bars are standard errors.

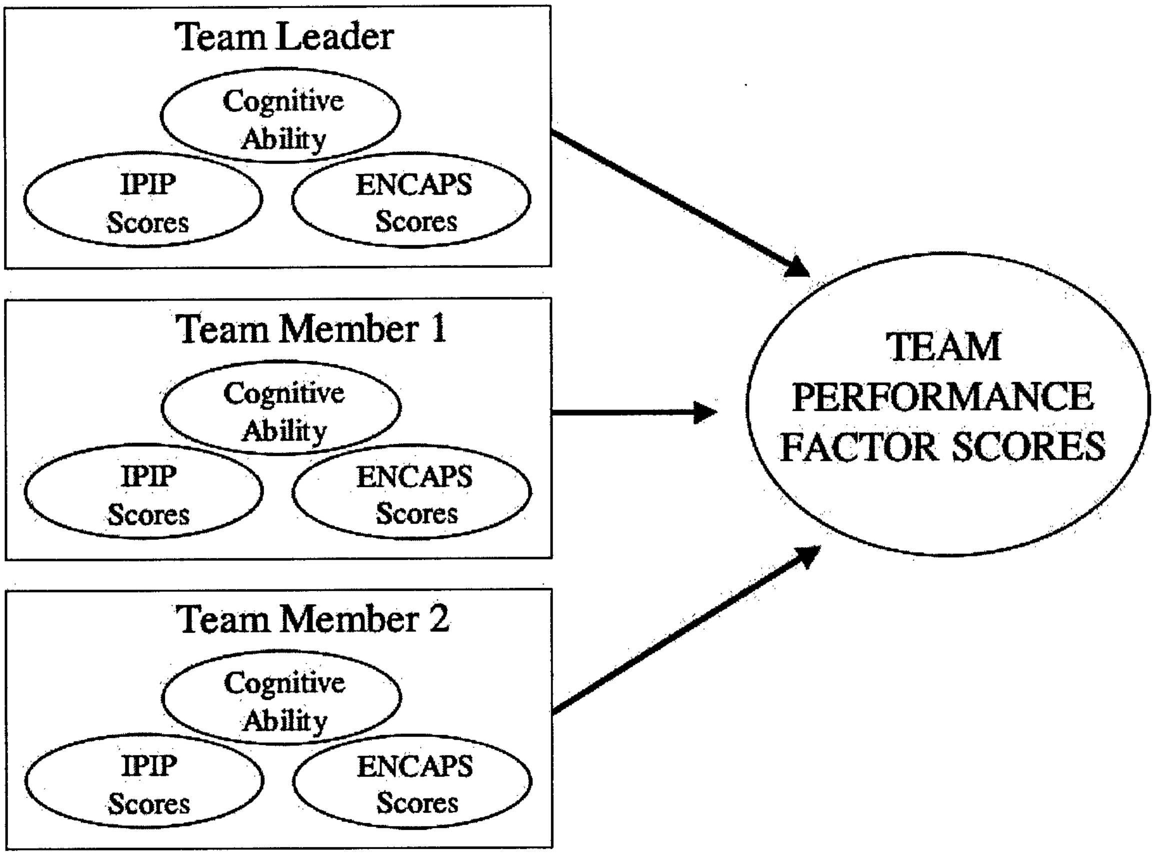


Figure 9. Illustration of the 'many-to-one' model of the final set of regression analyses.

Table 1

Possible team configurations based on cognitive and Social Orientation ability measures in the experimental design

Team Leader (Cognitive / Social Orientation)	Team Member 1 – Team Member 2 (Cognitive / Social Orientation)	Number of Teams to Complete Experiment
HH	HH – HH	12 teams
HH	HL – HL	11 teams
HH	LH – LH	11 teams
HH	LL – LL	10 teams

Note. Team leader is always high in both cognitive and social orientation abilities. Other team members are categorized as high or low in both cognitive and Social Orientation abilities.

Table 2

Dependant Variables Measuring Individual Performance

Dependant Variable	Description
Individual Damage per Engagement	A measure of the average number of times a team member was shot during encounters with hostile agents
Individual Total Player Damage	A measure of the average number of times a team member was shot during a full task
Individual Percent Ammunition Used on Hostiles	A measure of the amount of ammunition used on relevant targets as opposed to wasted on irrelevant targets or friendly agents
Individual Shots per Kill	A measure of the average number of bullets used to eliminate hostile agents encountered in the environment (with careful aim, hostile agents could be eliminated with one bullet)
Individual Time per Kill	A measure of the average amount of time between a team member encountering an agent and the agent being eliminated

Table 3

Composite Dependant Variables Measuring Team Performance

Dependant Variable	Description
Team Composite Damage per Engagement	The average 'Damage per Engagement' of the three team members
Team Composite Total Player Damage	The average 'Total Player Damage' of the three team members
Team Composite Percent Ammunition Used on Hostiles	The average 'Percent Ammunition Used on Hostiles' of the three team members
Team Composite Shots per Kill	The average 'Shots per Kill' of the three team members
Team Composite Time per Kill	The average 'Time per Kill' of the three team members

Table 4

Dependant Variables Measuring Team Performance

Dependant Variable	Description
Team Time to Completion	A measure of the average number of seconds required for the team to complete the tasks
Team VIP Damage	A measure of the number of times the team allowed the VIP to take damage from hostile agents
Team Percent Time VIP Guarded	A measure of the amount of time the team kept at least one member within a small distance of the VIP
Team Percent Time VIP in Danger	A measure of the amount of time that hostile agents got within a short range of the VIP

Table 5

Results of principal components factor analysis of individual level dependant variables.

Dependant Variables	Individual Level Factors	
	"Combat Effectiveness"	"Shooting Efficiency"
Individual Damage per Engagement	**0.95**	-0.02
Individual Total Player Damage	**0.88**	0.08
Individual Percent Ammo Used on Hostiles	-0.39	**0.63**
Individual Shots per Kill	0.03	**0.88**
Individual Time per Kill	0.25	**0.67**

Note. Bold coefficients indicate significant dependant variable factor loadings.

Table 6

Results of principal components factor analysis of team level dependant variables.

Dependant Variables	Team Level Factors		
	"Coordinative Ability"	"VIP Protection"	"Shooting Type"
Team Composite Damage per Engagement	**0.91**	0.01	0.0
Team Composite Total Player Damage	**0.94**	-0.07	-0.1
Team Composite Percent Ammo Used on Hostiles	-0.39	-0.15	**0.5**
Team Composite Shots per Kill	-0.01	-0.01	**0.8**
Team Composite Time per Kill	0.03	0.36	**0.5**
Team Time to Completion	**0.81**	0.06	-0.0
Team VIP Damage	0.15	**0.83**	0.0
Team Percent Time VIP Guarded	0.42	**-0.62**	0.2
Team Percent Time VIP in Danger	0.10	**0.79**	0.2

Note. Bold coefficients indicate significant dependant variable factor loadings.

Table 7

Regression Analysis Results for Individual Cognitive and IPIP Scores Predicting "Combat Effectiveness"

Variable	Unstandardized Parameter Estimate	Standard Error
Cognitive factor	**-0.25**	0.08
Extraversion	**0.02**	0.01
Neuroticism	**-0.04**	0.01
Conscientiousness	0.02	0.01
Agreeableness	**0.03**	0.01
Openness to Experience	0.01	0.01

Note. Model: F (6,125) = 6.66, $p < 0.01$.

Bold type indicates p-value less than 0.05.

Adjusted $R^2 = 0.21$.

Table 8

Regression Analysis Results for Individual Cognitive and ENCAPS Scores Predicting "Shooting Efficiency"

Variable	Unstandardized Parameter Estimate	Standard Error
Cognitive factor	-0.14	0.09
Social Orientation	**0.02**	0.01
Achievement Motivation	-0.01	0.01
Stress Tolerance	0.01	0.01

Note. Model: F (4,127) = 3.55, $p < 0.01$.

Bold type indicates p-value less than 0.05.

Adjusted $R^2 = 0.07$.

Table 9a

Regression Analysis Results for Synergy Model Cognitive and IPIP Scores Predicting "VIP Protection"

Variable	Unstandardized Parameter Estimate	Standard Error
Cognitive factor	0.08	0.23
Extraversion	1.3×10^{-5}	1.0×10^{-5}
Neuroticism	-3.2×10^{-6}	9.0×10^{-6}
Conscientiousness	2.0×10^{-5}	9.9×10^{-6}
Agreeableness	$\underline{-2.0 \times 10^{-5}}$	1.0×10^{-5}
Openness to Experience	-2.0×10^{-5}	9.5×10^{-6}

Note. Model: $F\ (6,37) = 2.50, p < 0.05$.

Underlined type indicates p-value less than 0.06.

Adjusted $R^2 = 0.17$.

Table 9b

Regression Analysis Results for Synergy Model Cognitive and ENCAPS Scores Predicting "Shooting Type"

Variable	Unstandardized Parameter Estimate	Standard Error
Cognitive factor	0.30	0.25
Social Orientation	**-7.2×10^{-7}**	3.0×10^{-7}
Achievement Motivation	**-5.2×10^{-6}**	2.3×10^{-6}
Stress Tolerance	**3.2×10^{-6}**	1.3×10^{-6}

Note. Model: $F(4,127) = 3.69, p < 0.02$.

Bold type indicates p-value less than 0.05.

Adjusted $R^2 = 0.20$.

Table 10a

Regression Analysis Results for Weakest-Link Model Cognitive and IPIP Scores Predicting "Coordinative Ability"

Variable	Unstandardized Parameter Estimate	Standard Error
Cognitive factor	**-0.56**	0.14
Extraversion	0.04	0.02
Neuroticism	**-0.06**	0.02
Conscientiousness	-7.0×10^{-4}	0.03
Agreeableness	0.02	0.03
Openness to Experience	0.04	0.03

Note. Model: $F\ (6,37) = 4.95, p < 0.01$.

Bold type indicates p-value less than 0.05.

Adjusted $R^2 = 0.36$.

Table 10b

Regression Analysis Results for Weakest-Link Model Cognitive and IPIP Scores Predicting "VIP Protection"

Variable	Unstandardized Parameter Estimate	Standard Error
Cognitive factor	0.14	0.14
Extraversion	0.01	0.02
Neuroticism	-0.01	0.02
Conscientiousness	0.04	0.03
Agreeableness	**-0.07**	0.03
Openness to Experience	**-0.10**	0.03

Note. Model: F (6,37) = 4.45, $p < 0.01$.

Bold type indicates p-value less than 0.05.

Adjusted $R^2 = 0.32$.

Table 10c

Regression Analysis Results for Weakest-Link Model Cognitive and ENCAPS Scores Predicting "Coordinative Ability"

Variable	Unstandardized Parameter Estimate	Standard Error
Cognitive factor	**-0.43**	0.13
Social Orientation	0.01	0.01
Achievement Motivation	6.2×10^{-4}	0.02
Stress Tolerance	**-0.04**	0.01

Note. Model: F (4,39) = 5.78, $p < 0.01$.

Bold type indicates p-value less than 0.05.

Adjusted $R^2 = 0.31$.

Table 10d

Regression Analysis Results for Weakest-Link Model Cognitive and ENCAPS Scores Predicting "Shooting Type"

Variable	Unstandardized Parameter Estimate	Standard Error
Cognitive factor	-0.02	0.13
Social Orientation	-0.01	0.01
Achievement Motivation	**-0.07**	0.03
Stress Tolerance	**0.03**	0.01

Note. Model: $F\ (4,127) = 4.19$, $p < 0.01$.

Bold type indicates p-value less than 0.05.

Adjusted $R^2 = 0.23$.

Table 11a

Regression Analysis Results for Average Model Cognitive and IPIP Scores Predicting "Coordinative Ability"

Variable	Unstandardized Parameter Estimate	Standard Error
Cognitive factor	**-0.66**	0.23
Extraversion	0.05	0.03
Neuroticism	**-0.08**	0.04
Conscientiousness	-0.01	0.04
Agreeableness	0.03	0.05
Openness to Experience	0.04	0.05

Note. Model: F (6,37) = 3.66, $p < 0.01$.

Bold type indicates p-value less than 0.05.

Adjusted $R^2 = 0.27$.

Table 11b

Regression Analysis Results for Average Model Cognitive and IPIP Scores Predicting "VIP Protection"

Variable	Unstandardized Parameter Estimate	Standard Error
Cognitive factor	0.04	0.25
Extraversion	0.04	0.03
Neuroticism	-0.02	0.04
Conscientiousness	0.06	0.04
Agreeableness	-0.10	0.05
Openness to Experience	-0.08	0.05

Note. Model: $F\ (6,37) = 2.22, p < 0.07$.

Bold type indicates p-value less than 0.05.

Adjusted $R^2 = 0.15$.

Table 11c

Regression Analysis Results for Average Model Cognitive and ENCAPS Scores Predicting "Coordinative Ability"

Variable	Unstandardized Parameter Estimate	Standard Error
Cognitive factor	**-0.59**	0.20
Social Orientation	0.02	0.01
Achievement Motivation	-0.01	0.03
Stress Tolerance	-0.04	0.02

Note. Model: F (4,39) = 3.67, $p < 0.01$.

Bold type indicates p-value less than 0.05.

Adjusted $R^2 = 0.22$.

Table 11d

Regression Analysis Results for Average Model Cognitive and ENCAPS Scores Predicting "Shooting Type"

Variable	Unstandardized Parameter Estimate	Standard Error
Cognitive factor	0.01	0.21
Social Orientation	**-0.03**	0.02
Achievement Motivation	**-0.07**	0.03
Stress Tolerance	**0.05**	0.02

Note. Model: F (4,39) = 2.71, $p < 0.05$.

Bold type indicates p-value less than 0.05.

Adjusted $R^2 = 0.14$.

Table 12

Regression Analysis Results for Individual Cognitive and IPIP Scores Predicting "Coordinative Ability"

Variable	Unstandardized Parameter Estimate	Standard Error
Cognitive factor (Leader)	-0.51	0.39
Cognitive factor (Member 1)	0.08	0.18
Cognitive factor (Member 2)	**-0.41**	0.15
Extraversion (Leader)	**0.06**	0.02
Extraversion (Member 1)	-0.01	0.01
Extraversion (Member 2)	0.03	0.02
Neuroticism (Leader)	-0.03	0.02
Neuroticism (Member 1)	**-0.03**	0.02
Neuroticism (Member 2)	-0.03	0.02

Note. Model: F (9,34) = 4.23, $p < 0.01$.

Bold type indicates p-value less than 0.05.

Adjusted $R^2 = 0.40$.

Table 13

Regression Analysis Results for Individual Cognitive and IPIP Scores Predicting "VIP Protection"

Variable	Unstandardized Parameter Estimate	Standard Error
Extraversion (Leader)	**0.04**	0.02
Extraversion (Member 1)	0.00	0.01
Extraversion (Member 2)	**-0.04**	0.02
Neuroticism (Leader)	-0.03	0.02
Neuroticism (Member 1)	**0.05**	0.02
Neuroticism (Member 2)	**-0.04**	0.02

Note. Model: F (6,37) = 4.94, $p < 0.01$.

Bold type indicates p-value less than 0.05.

Adjusted $R^2 = 0.35$.

Table 14

Regression Analysis Results for Individual Cognitive and ENCAPS Scores Predicting "Shooting Type"

Variable	Unstandardized Parameter Estimate	Standard Error
Social Orientation (Leader)	-0.03	0.02
Social Orientation (Member 1)	**-0.03**	0.01
Social Orientation (Member 2)	0.02	0.01
Achievement Motivation (Leader)	**-0.05**	0.02
Achievement Motivation (Member 1)	-0.02	0.02
Achievement Motivation (Member 2)	**-0.04**	0.02
Stress Tolerance (Leader)	0.01	0.01
Stress Tolerance (Member 1)	-0.01	0.01
Stress Tolerance (Member 2)	**0.04**	0.01

Note. Model: $F\ (9,34) = 3.37, p < 0.01$.

Bold type indicates p-value less than 0.05.

Adjusted $R^2 = 0.33$.

Table 15

Variables Recorded by Data Logging Tool

Variable Name	Description
Spawn Time	Records the timestamp of when each team member or computer controlled agent appears in the environment
Damage Taken	Records the timestamp of any time a team member or computer controlled agent is hit with a weapon
Weapon Fired	Records the timestamp of any time a weapon is being used
Button Pushed	Records the timestamp and position of any button activated in the environment
Door Opened / Closed	Records the timestamp for any doors or other barriers opening or closing
Ammunition Gained	Records the timestamp any time a team member picks up ammunition as well as the amount picked up
Flashlight / Tool Use	Records the timestamp for any time a flashlight or other tool is used by a team member
Location	Records the position of every team member and computer controlled agent in the environment every 0.4 seconds
Entity Range	Calculates and records the distance of every computer controlled agent from each of the team members every 0.4 seconds